THE DESIGN, CONSTRUCTION
AND USE OF A RIVER TRAY
Submitted by:
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THE UNIVERSITY OF ALBERTA

THE DESIGN, CONSTRUCTION AND USE OF A RIVER TRAY

A DISSERTATION

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FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

by

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UNDER THE DIRECTION OF

T. BLENCH

EDMONTON, ALBERTA,

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ABSTRACT

A river tray has been designed and constructed for basic river research, solution of practical problems and the demonstration of principles. Preliminary tests show bed waves develop rapidly, meanders develop as in models by other workers, scour at principal points accords reasonably with field results, and changes of regime can be induced by altering sediment distribution without changing discharge. Cinephotographic technique is being developed and is proving promising. Auxiliary arrangements for the study of sediment properties relevant to river behaviour are being developed.

THE DESIGN, CONSTRUCTION AND USE OF A RIVER TRAY

HISTORY With the prospect in 1952 of a New Engineering Building at the University of Alberta, affording a larger and better equipped hydraulics laboratory, a river tray became a practical possibility. The instructional use of such a tray would be for demonstrating canal and river behaviour, as well as flow through certain three-dimensional models for undergraduate and graduate courses. Accordingly funds for constructing and equipping a river tray were provided in the 1953-54 budget of the Civil Engineering Department.

To adapt the proposed facilities for a program of quantitative river research would have required equipment far in excess of that justifiable for routine instruction. Therefore an initial National Research Council Grant, Number 364 of 1953, for $4,000. was obtained. Actually initial planning started late in 1952, so that a workable scheme of action was ready in March, 1953.

PLANNING The maximum space available was 30 ft. by 60 ft. This fixed the tray size at 20 ft. by 50 ft. to allow accessibility.

As the fundamental object of several years of research is to study, quantitatively, problems related to meandering and specific river control works, the discharge and sand load had to be limited by the requirement of

inducing at least one full meander bend, plus a margin, to form. (All river parameters, e.g. meander length, slope, width, depend ultimately on discharge and load; See Refs. 1, 4, 5, 6, 7). Thus a peak discharge of 0.4 cusecs was accepted for design. As the usual meander belt width appeared to be about half a tray width, the decision was taken that the tray should be divided longitudinally and filled with two grades of sand so that initial experiments could be run in duplicate for comparison of the effect of sand size; for various technical reasons a coarse sand may be expected to cause some of the phenomena of boulder streams.

A major factor responsible for the backwardness of research in river behaviour has been the slow and varied development of meanders in nature. With the model discharge range imposed by considerations just stated, the model rivers would represent behaviour of a river of the size of the North Saskatchewan to a timescale of about 1/100; therefore what might be deemed a fair representation of a cycle of meander occurrences, even under perpetual high-river conditions, may be assumed to require about a week of uninterrupted model running. Therefore, the only satisfactory way to record happenings quantitatively, at reasonable cost in an acceptable time, appeared to be by cinematograph. So the plans allowed for a cinecamera with a control device that could take photos at various time intervals, and with a magazine to hold film for several days. Although the hope has been that the results could be turned into "speeded-up" instructional films, exactly like those of similar type made by botanists, technical

difficulties of photographing a large area containing rippling water under ordinary fluorescent lighting may prevent this hope from being fulfilled at present; however, there is no reason to doubt the ability of the photographic method to give records for quantitative analysis.

Another major time-wasting factor in river experiments has been the long time required for a channel to adjust to regime if given an arbitrary start. The plans countered in two ways; first, by arranging to obtain sand that would have as nearly a regime grain-size distribution (Ref. 3) as possible; second, by adopting the fairly recent practice--of which an example was inspected at Colorado A & M College--of recirculating the sediment-load along with the water.

Study of regime sand-grain distribution has been backward for reasons that include the difficulty of making sufficient analyses rapidly. As the U. S. Corps of Engineers has developed, very recently, a commercially obtainable device for very rapid analysis, the plans arranged to obtain one. (Ref. 8, 9)

Finally, the neglected topic of slope variation due to meandering can now be studied with the assistance of automatic recording gauges developed in the U.S.A. and in Europe and commercially obtainable. Therefore plans were made to obtain one, as a start. (Ref. 10, 11, 12)

A programme to cover several years, without encroaching on work done elsewhere, was prepared. The intention, at the time of writing, is to attack bridge problems first, in the hope of showing a quick return for the money spent; a

large programme of basic work is in prospect later.

DETAILS OF ARRANGEMENTS AND EQUIPMENT

Plate 1 is a detailed plan with elevation of the whole river tray, consisting of a 20 x 49 ft. tank, 1.5 ft. deep, built of brick and lined with tarred felt. The concrete floor is that of the laboratory. The tray is divided longitudinally along its centre line by a diaphragm to form two units, each of which carries a model river in its own sand. Plate 2 is a photograph taken from the cinecamera stand, showing two model rivers ready to start from the canal stage; perspective effect has been compensated in enlarging the photo.

Reverting to Plate 1, water enters the tray at the extreme right from a flume run along the wall of the laboratory; the flume edge is made suitable for rapid adjustment or for controls. Each half of the tray has its own arrangements, mirror images of those of the other half. The sources of supply are the tanks marked 1 and 2 at the downstream end. They are connected into the city main, whose supply is regulated by a float valve. Thus the procedure of starting flow in one half tray is to operate the pump, shown just beside the tank (and, in detail, in the photo of Plate 3). This action draws water from the tank and forces it along the pipe-line running the length of the tray into the supply flume at the head of the tray; thence it runs through the river-bed, drops into the discharge flume at the downstream end, and finds its way complete with any sediment that has been picked up, back into the tank. While flow is en route

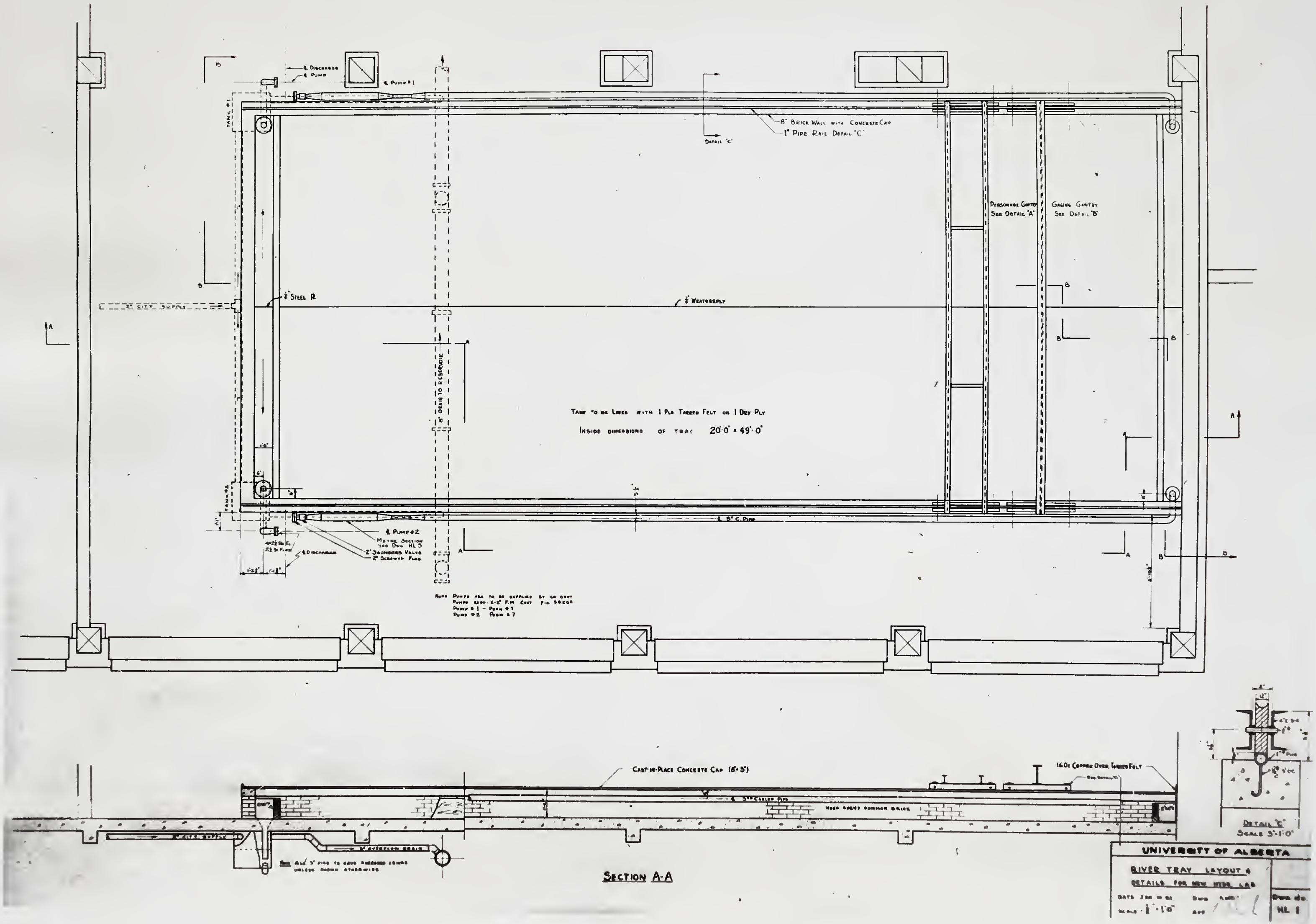

8" Brick Wall with Concrete Cap
1" Pipe Rail Detail "C"
Detail "C"
Personnel Gantry See Detail "A"
Gaging Gantry See Detail "B"
¾" Steel R
¾" Weatherply
Drain to Reservoir
Tank to be Lined with 1 Ply Tarred Felt on 1 Dry Ply
Inside dimensions of tray 20'-0" x 49'-0"
℄ Discharge
℄ Pump
℄ Pump #1
℄ Pump #2
Meter Section See Dwg HL 3
2" Saunders Valve
2" Screwed Plug
℄ Discharge
Cast-in-Place Concrete Cap (6"x5")
16 Oz Copper Over Tarred Felt
Hard Burnt Common Brick
Section A-A
Detail "C"
Scale 3"=1'-0"
University of Alberta
River Tray Layout &
Details for New Hydr Lab
Dwg No.
HL 1

PLATE No. 1


UNIVERSITY OF ALBERTA
DEPT OF CIVIL ENGINEERING
RIVER TRAY
TEST NO 1
01 DISCHARGE 01
045 SAND SIZE MM 02
00108 INT SLOPE 00084

PLATE No. 2

to the downstream end the city main continues to supply water. The sediment picked up by the river passes through to the pump again because of the design of the tank, whose details are in the working drawing of Plate 4. When circulation is fully established the city supply stops automatically.

Plate 3 shows a control valve above the pump. The intention is to operate this valve mechanically to impose a standard fluctuating hydrograph. The manometer connects to the venturi meter whose upstream tapping is visible in the photo. A portion of rail for the travelling gantries is also visible.

Along the tank's long walls run level rails to carry the two gantries outlined in Plates 1 & 3. One of these is to carry operators only. The other is for standard and special instruments and is shown in the photo of Plate 5. The vibrating point limnigraph is in position in its carriage on the rails that run the length of the gantry, but the point attachment that picks up the water-level records is missing. To accelerate regrading of the river valley, scraper blades have been built into the gantry.

Plate 6 is of the rapid sand analyser obtained through the U.S. Corps of Engineers. A part of it can be seen just behind the limnigraph in Plate 5.

The sands in the tray at present are of 0.27 mm. in the one compartment and 0.41 mm. in the other, with their grading according to the lograithmic normal distribution, (Plates 7, 8) for reasons given in Ref. 3; the 0.27 mm. sand was found fitting this distribution very well, but the coarser

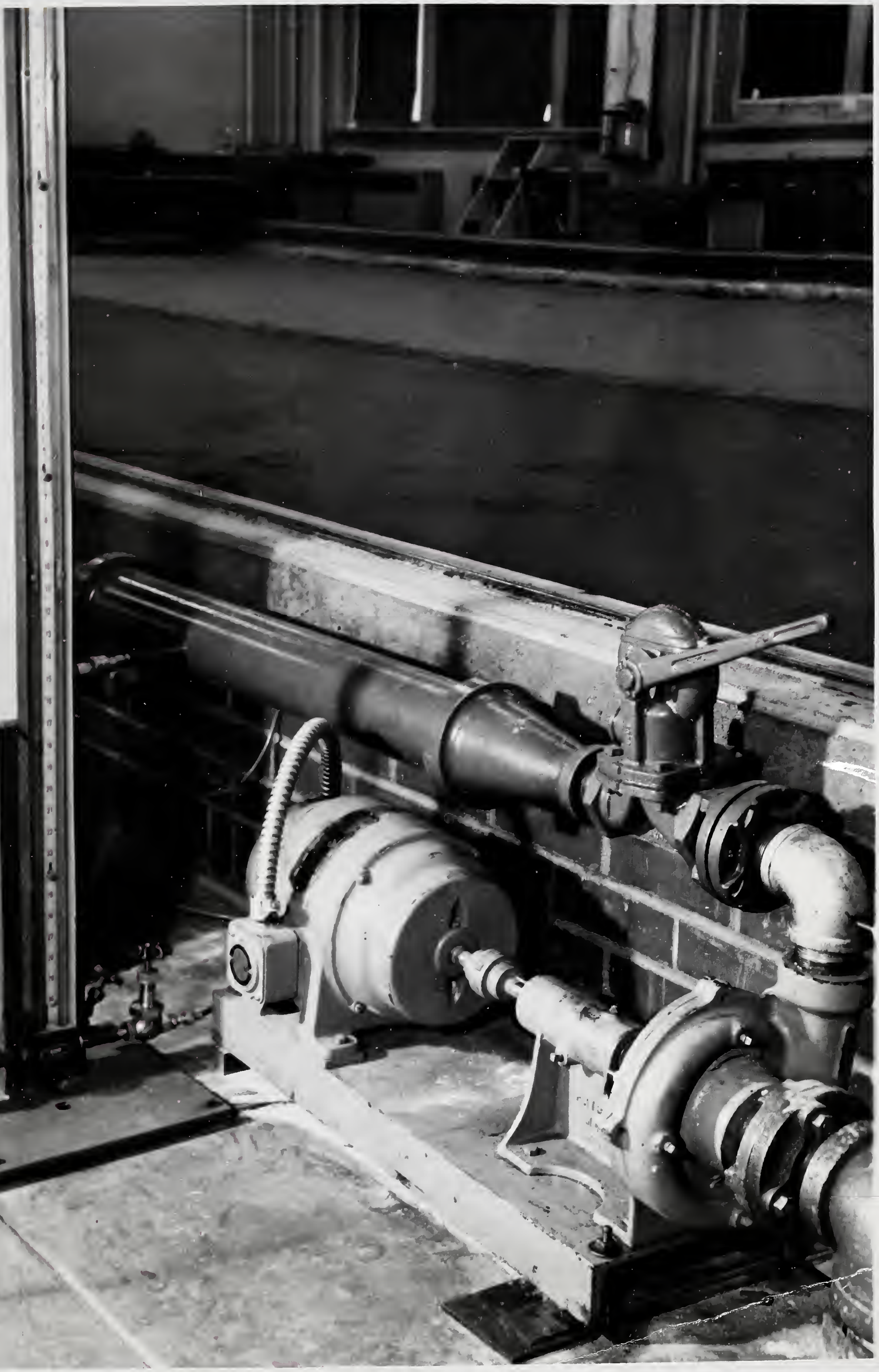
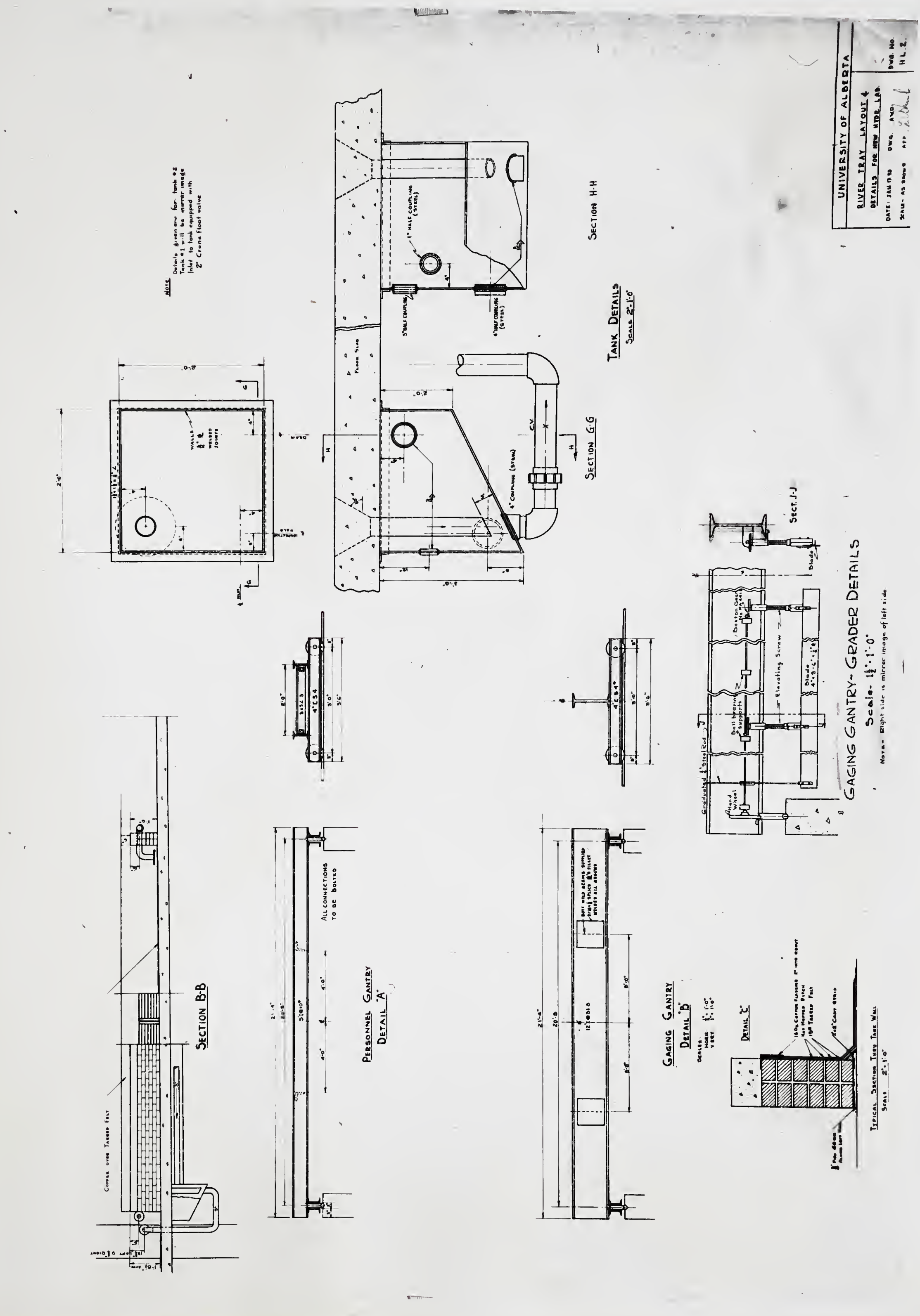


PLATE N^{o} 3



UNIVERSITY OF ALBERTA
RIVER TRAY LAYOUT 4
DETAILS FOR NEW HYDR. LAB.
TANK DETAILS
SECTION H-H
SECTION G-G
SECTION B-B
PERSONNEL GANTRY DETAIL "A"
ALL CONNECTIONS TO BE BOLTED
GAGING GANTRY DETAIL "B"
DETAIL "C"
GAGING GANTRY- GRADER DETAILS
SECT. J-J
Elevating Screw
Blade
Hand Wheel
Note- Right side is mirror image of left side
TYPICAL SECTION THRU TANK WALL

PLATE No. 4

PLATE N°. 5

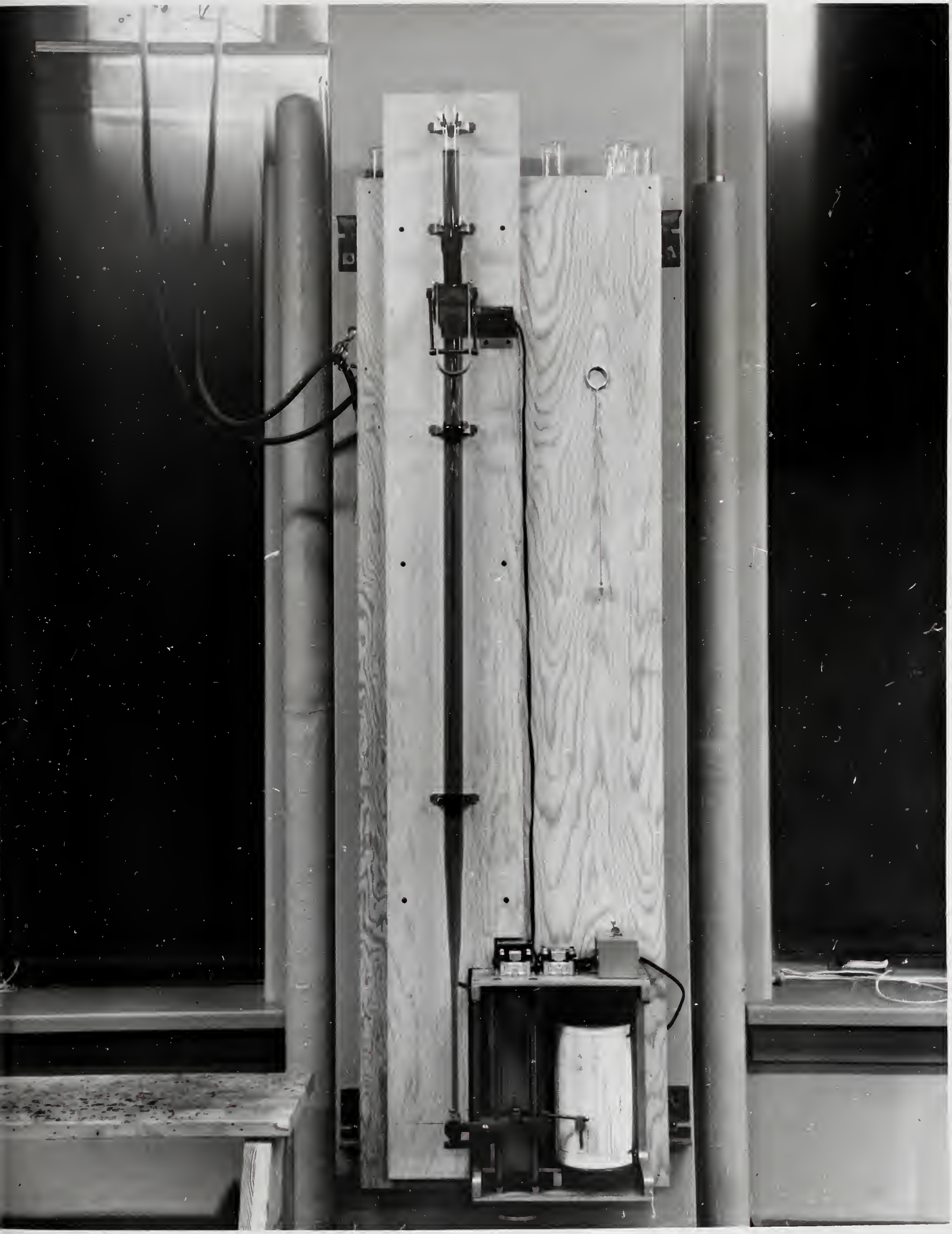


PLATE No. 6

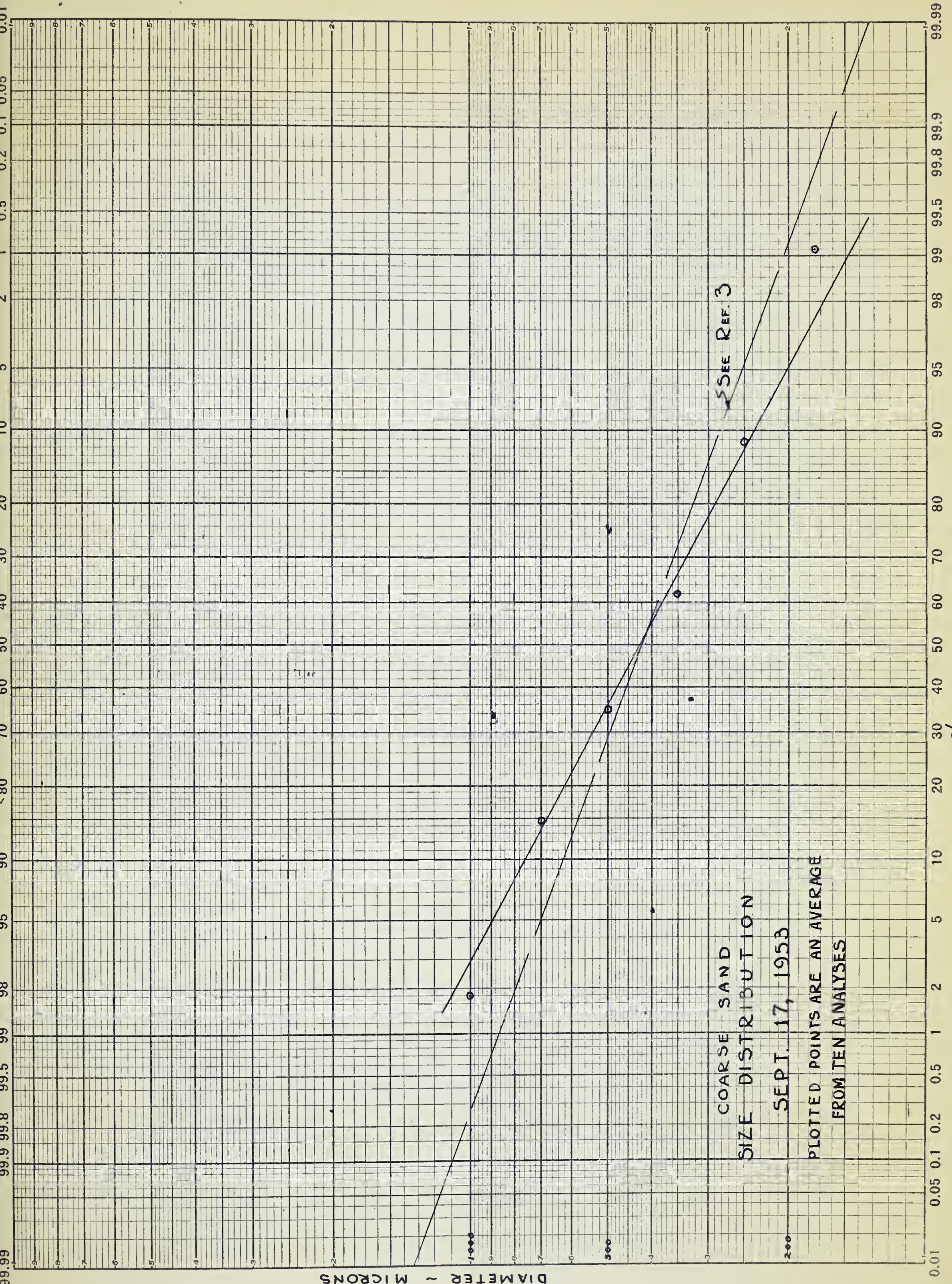

COARSE SAND
SIZE DISTRIBUTION
SEPT. 17, 1953
PLOTTED POINTS ARE AN AVERAGE
FROM TEN ANALYSES
SEE REF. 3
% COARSER THAN
DIAMETER ~ MICRONS

PLATE No. 7

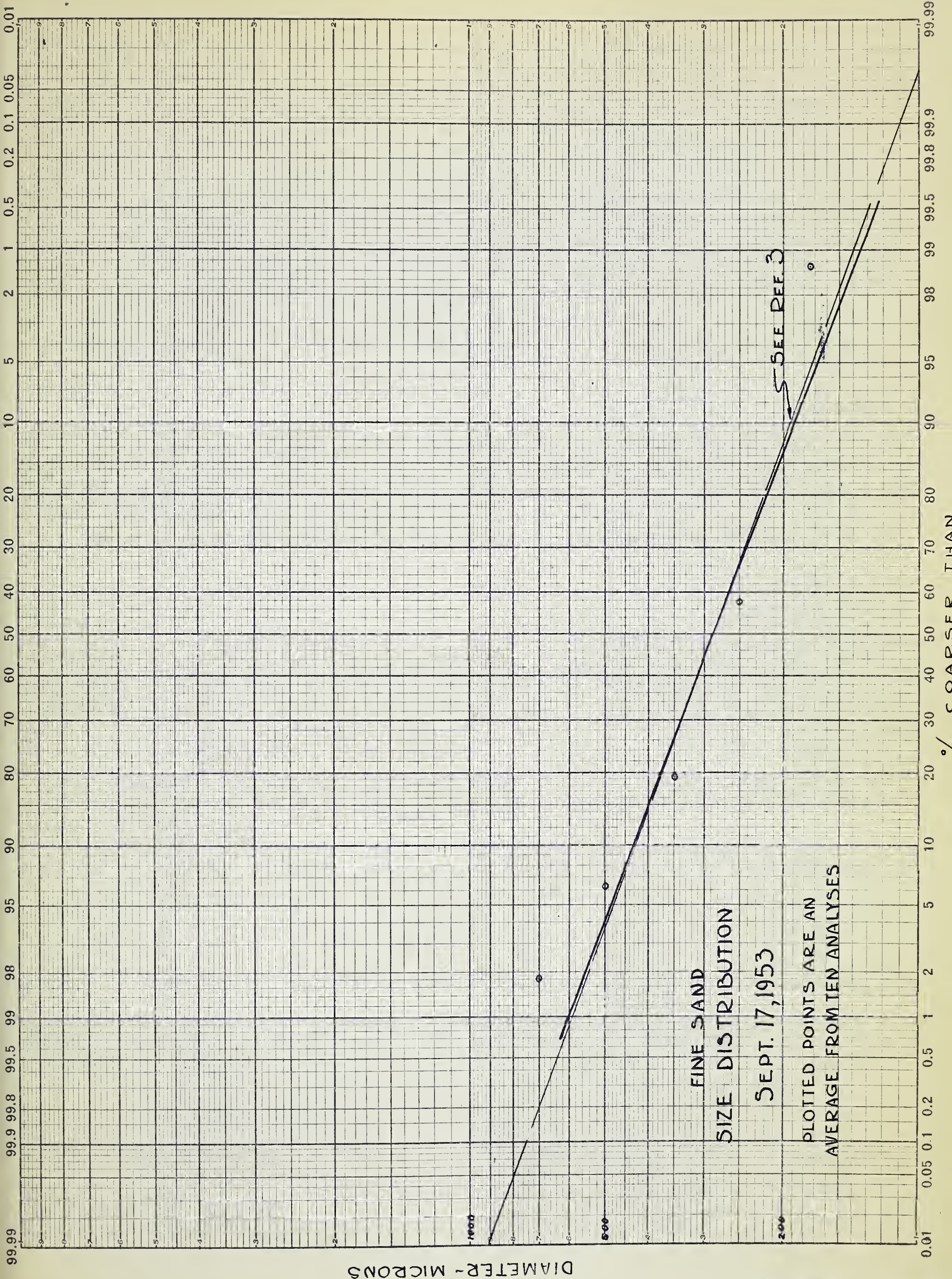

FINE SAND
SIZE DISTRIBUTION
SEPT. 17, 1953
PLOTTED POINTS ARE AN
AVERAGE FROM TEN ANALYSES
SEE REF 3
% COARSER THAN
DIAMETER - MICRONS
1000
500
200

PLATE No. 8

sand needed some removal of coarse material to make it an acceptable approximation.

The cinecamera is not marked in any Plate, but is located on a stand at about roof level on the tank centerline where it cuts the laboratory wall on the left of Plate 1. The best assessment of the suitability of its location is from Plate 2, for the bottom of the photo is only 5 feet from the outlet flume of the tray.

<u>TESTING</u> It has been found that the original estimates of time for tests were over optimistic. Due to delays and shortage of time it has been possible to carry out only two tests, but the results from these have been gratifying.

The results from these tests have shown that the river tray will give qualitative and quantitative answers on river behaviour that check with actual cases.

In the Preliminary Test a canal was dug straight through the coarse sand compartment, similar to that shown in Plate 2, but without any attempt to fix the start of meandering. The canal size was chosen according to regime theory (equations given in Appendix 1) for 0.1 cusec (see Plates 9, 10, 11) and the slope was twice normal canal slope because it is believed meandering requires up to 100% extra slope. ($\not{S}$ Reg. = .00084, $\not{S}$ act. = .0017) Initial draw down at the downstream end resulted in initial excess charge at the head which caused the channel to develop into a very natural looking river of the building-up types, (Multiple channelled and rapidly changing), in spite of the steady discharge. The local draw

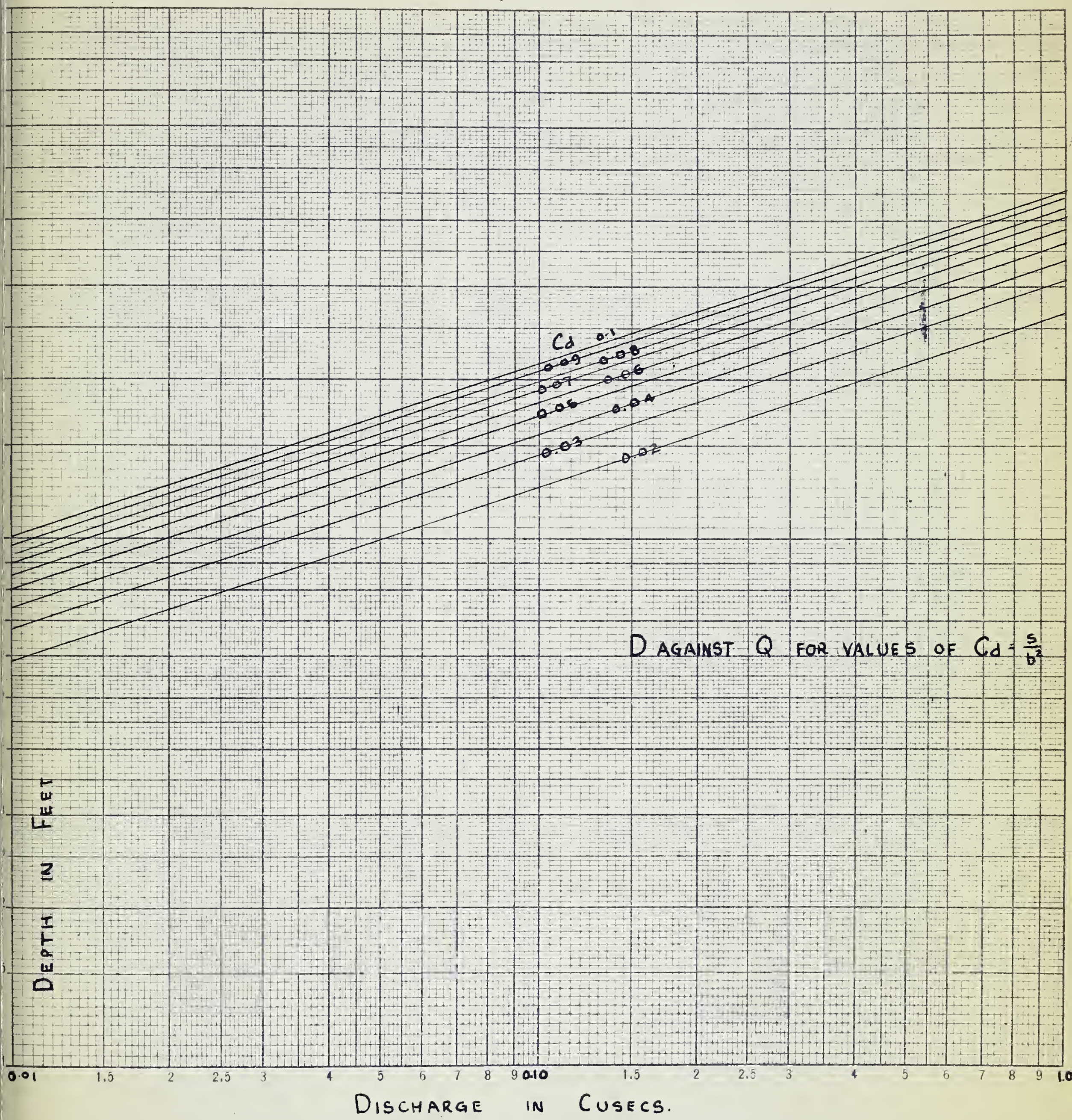

Cd 0.1
0.09 0.08
0.07 0.06
0.05 0.04
0.03 0.02
D AGAINST Q FOR VALUES OF Cd = s/b²
DEPTH IN FEET
0.01 1.5 2 2.5 3 4 5 6 7 8 9 0.10 1.5 2 2.5 3 4 5 6 7 8 9 1.0
DISCHARGE IN CUSECS.

PLATE No. 9

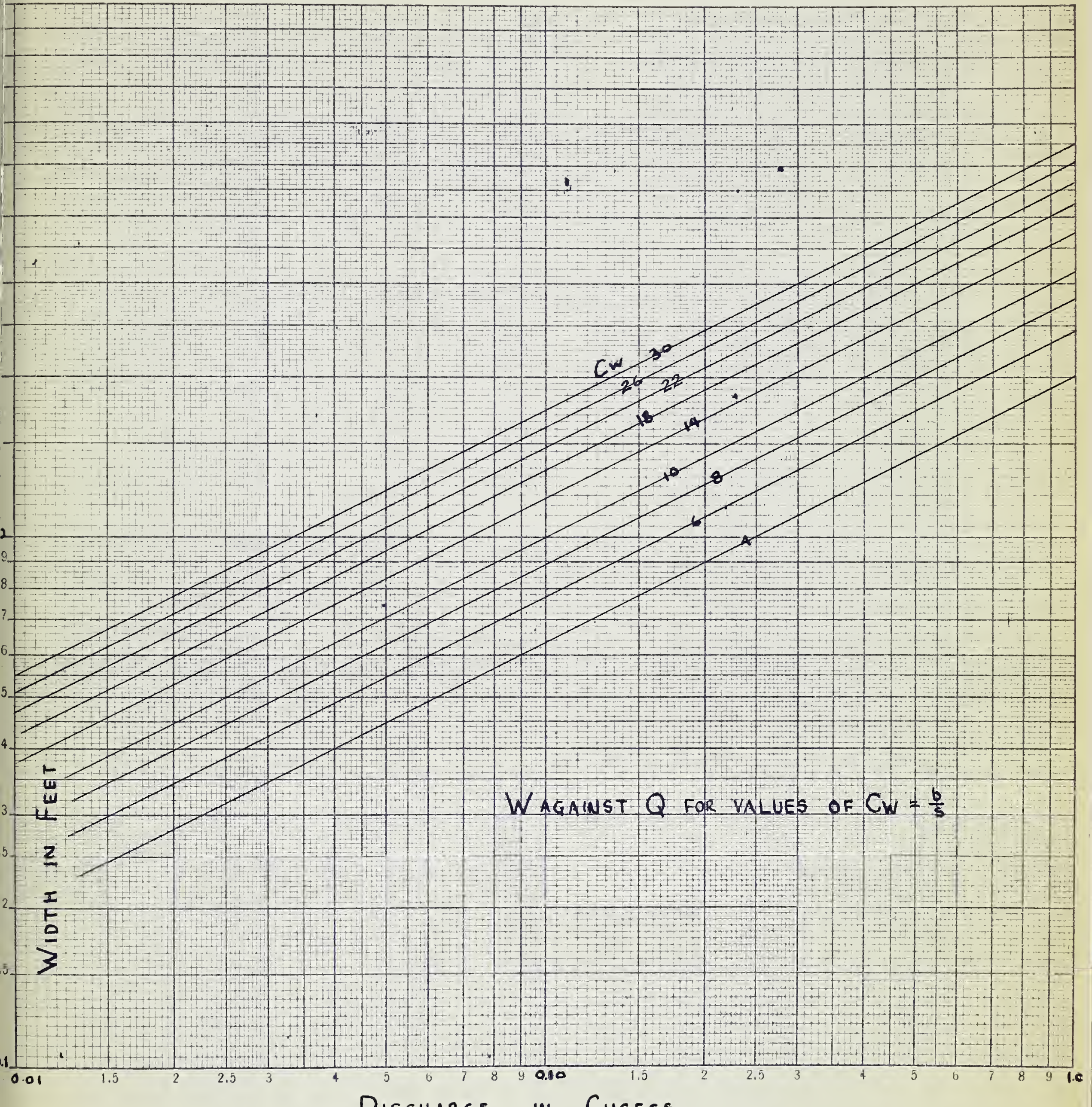
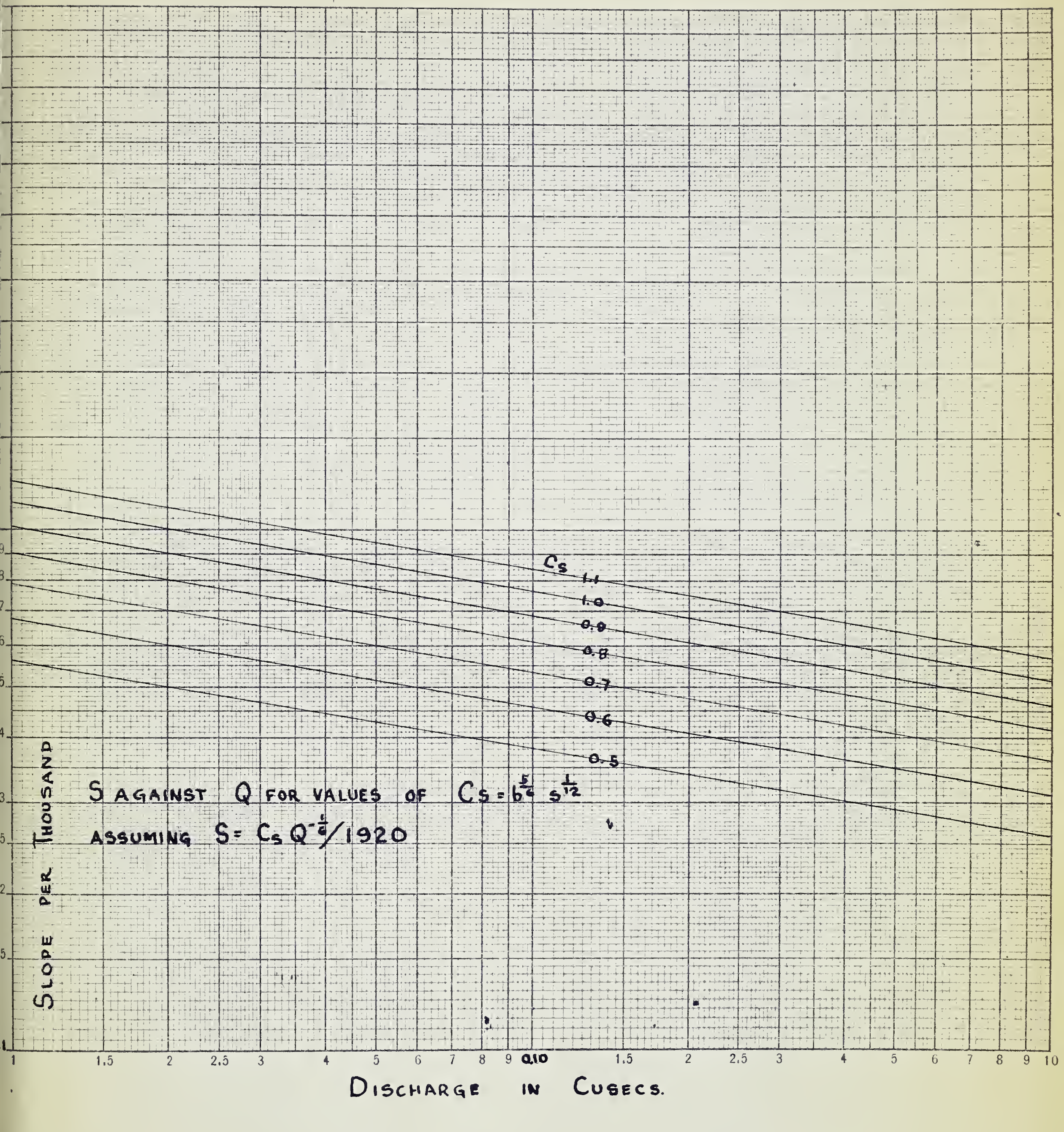

Cw 30
26
22
18
14
10
8
6
4
W against Q for values of Cw = b/s
Width in Feet
Discharge in Cusecs.
0·01
1.5
2
2.5
3
4
5
6
7
8
9
0.10
1.5
2
2.5
3
4
5
6
7
8
9
1.0

PLATE No 10



S AGAINST Q FOR VALUES OF Cs = b^5/6 s^1/12
ASSUMING S = Cs Q^-1/6 / 1920
Cs
1.1
1.0
0.9
0.8
0.7
0.6
0.5
SLOPE PER THOUSAND
DISCHARGE IN CUSECS.
1
1.5
2
2.5
3
4
5
6
7
8
9
0.10
1.5
2
2.5
3
4
5
6
7
8
9
10

PLATE No. 11

down was due to a small error in the elevation of the down-stream weir crest. A small difference in elevation of the crest can cause the local slope to double resulting in rapid bed movement at the downstream end. It is interesting to note that this point could be used in later tests to develop a river of the building up type.

After the Preliminary Test a formal test No. 1 was set up with canals in both the fine and coarse sands, each having an initial bend at the head to fix the start of meandering (See Plate 2).

The development of the coarse sand river was very slow. To speed up the development, the slope was induced to steepen by adding sand in the downstream sump so it would enhance the bed load at the head; the discharge was also decreased. With the combination of less discharge and added bed load the meander development went on much more rapidly. The meander development in the fine sand river started with no change in load or discharge. The discharge was later reduced for comparison with the coarse sand river.

From an estimate of the bed factor for the two sands it was thought that 1.3 times the regime slope would be just enough in excess to cause meandering.

	Coarse Sand	Fine Sand
Regime Slope	.00084	.00064
Actual Slope	.00109	.00083

The estimate of bed factor for the fine sand was close and with the above slope meandering occured. A wrong estimate in bed factor for the coarse sand would account for non meandering. The emperical rule ($b = 2\sqrt{m}$) for estimating

bed factor may not apply to the coarse sand. A much more satisfactory method of measuring bed factor is by flume experiments. A flume is being set up for this purpose.

Meander length and breadth in both tests were in the range found by other researchers for river models in sand ie. $Ml = 36Q^{\frac{1}{2}} \pm 50\%$ and $Mb = 16Q^{\frac{1}{2}} \pm 25\%$ (Reference 6)

	$\frac{Mb}{}$	$\frac{Ml}{}$
Fine Sand	$55Q^{\frac{1}{2}}$	$20Q^{\frac{1}{2}}$
Coarse Sand	$55Q^{\frac{1}{2}}$	$14.5Q^{\frac{1}{2}}$

Published results of other models state that some workers have experienced difficulty in getting the bed material to form in ripples. (Reference 13) In both tests carried out no difficulty of this kind has been encountered. The correct choice in the grading of the bed material has no doubt overcome this difficulty.

Checks on the grading of the bed material have shown little change, after some 250 hrs. of testing, which would also indicate a correct choice of bed material (See Plates 7, 8, 12, 13). Other researchers have found that changes in bed material have caused operational difficulties - long time to stability. (Reference 13)

Qualitative tests indicate close agreement with published river results. Observed scour depths on model spurs and around bridge piers were from 1.5 to twice the normal or regime depth. These results are in agreement with those given in References 1 and 14.

A bridge site was chosen on the fine sand river; Plate 14 is a plan of the area before the piers and approach road were constructed. The span of the bridge was based on

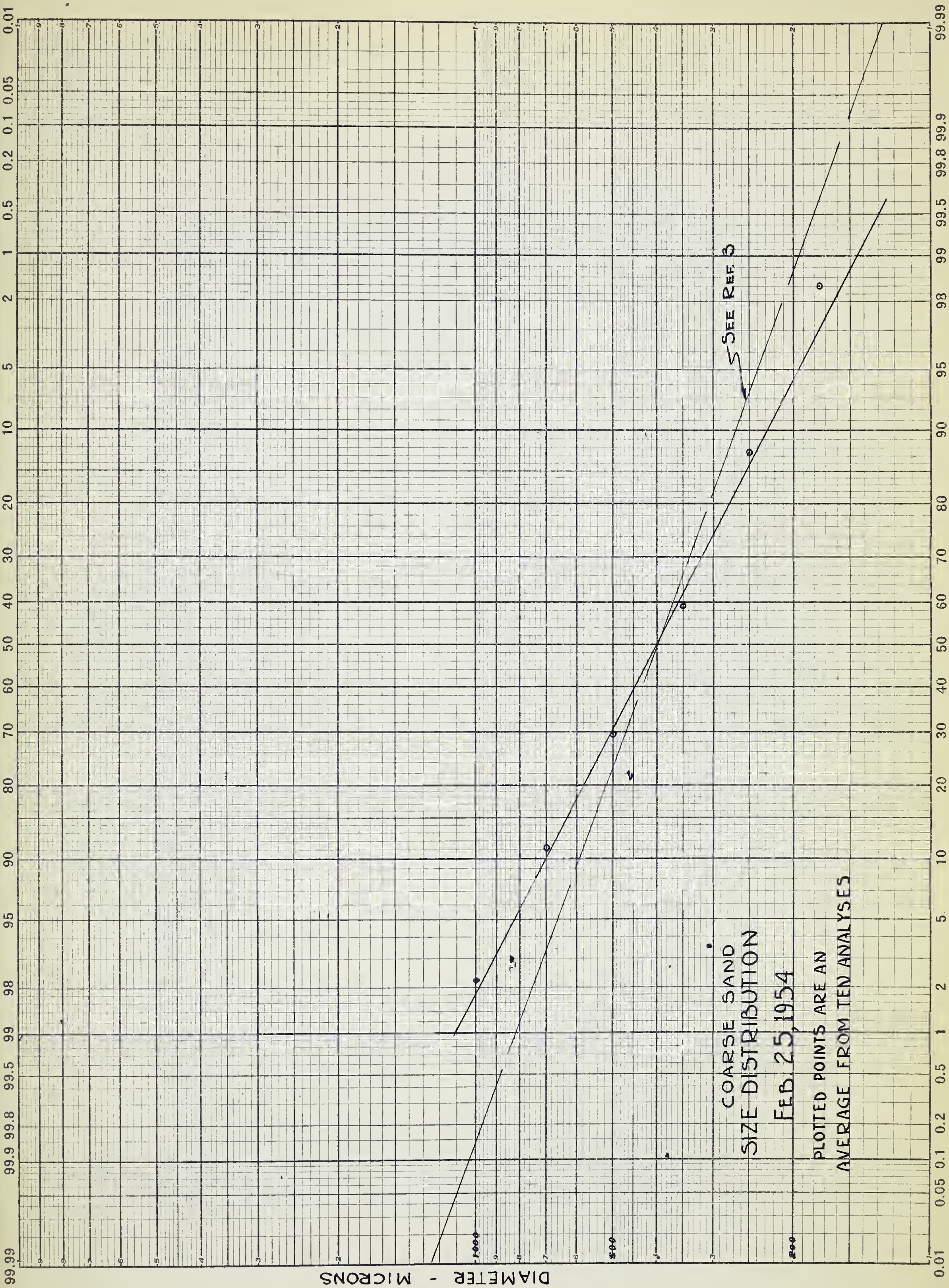

COARSE SAND
SIZE DISTRIBUTION
FEB. 25, 1954
PLOTTED POINTS ARE AN
AVERAGE FROM TEN ANALYSES
SEE REF. 3
% COARSER THAN
DIAMETER - MICRONS
1000
500
200

PLATE No. 12

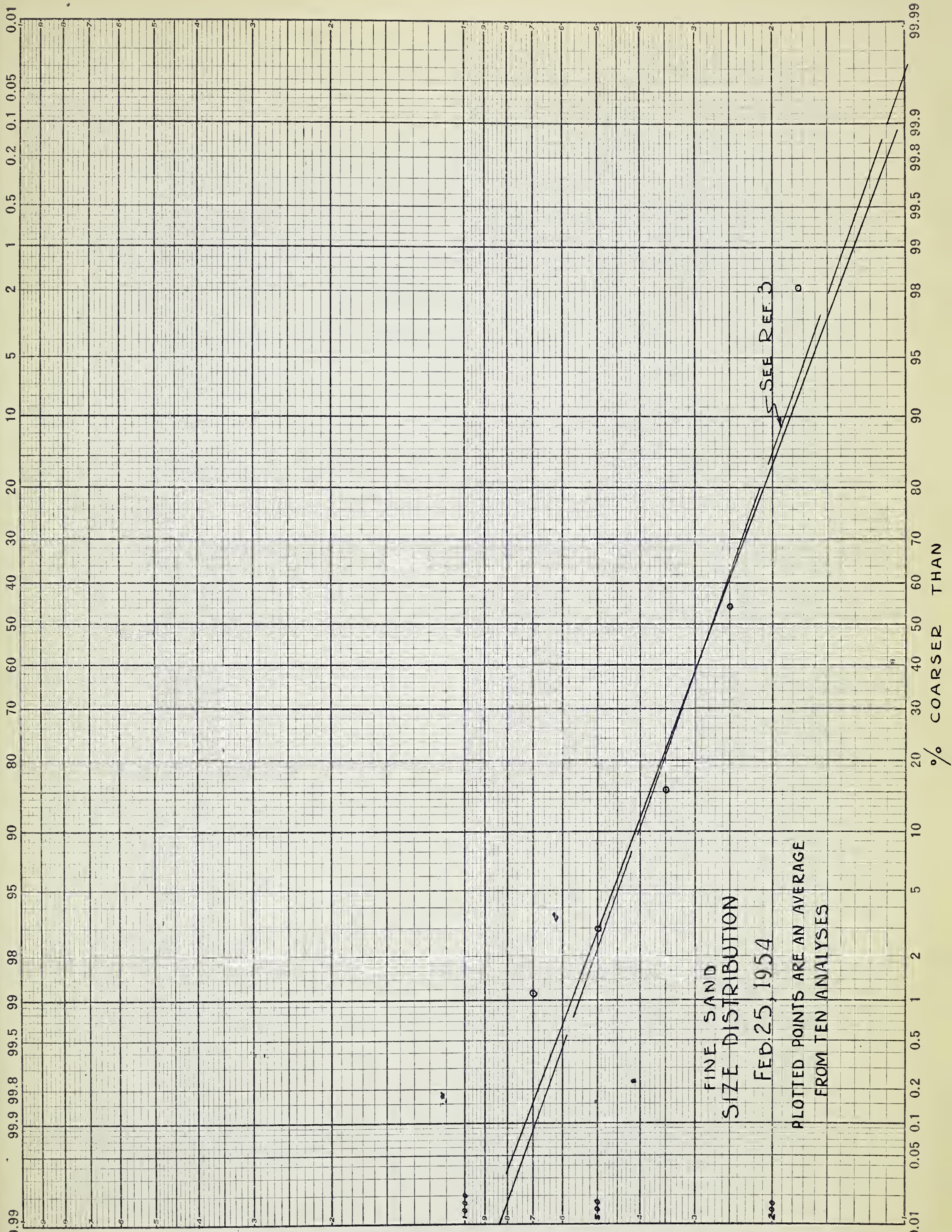

FINE SAND
SIZE DISTRIBUTION
FEB. 25, 1954
PLOTTED POINTS ARE AN AVERAGE
FROM TEN ANALYSES
SEE REF 3
% COARSER THAN
DIAMETER ~ MICRONS
1000
500
200

PLATE No. 13

$W = 2.67\ Q^{\frac{1}{2}}$ max. (Reference 1).

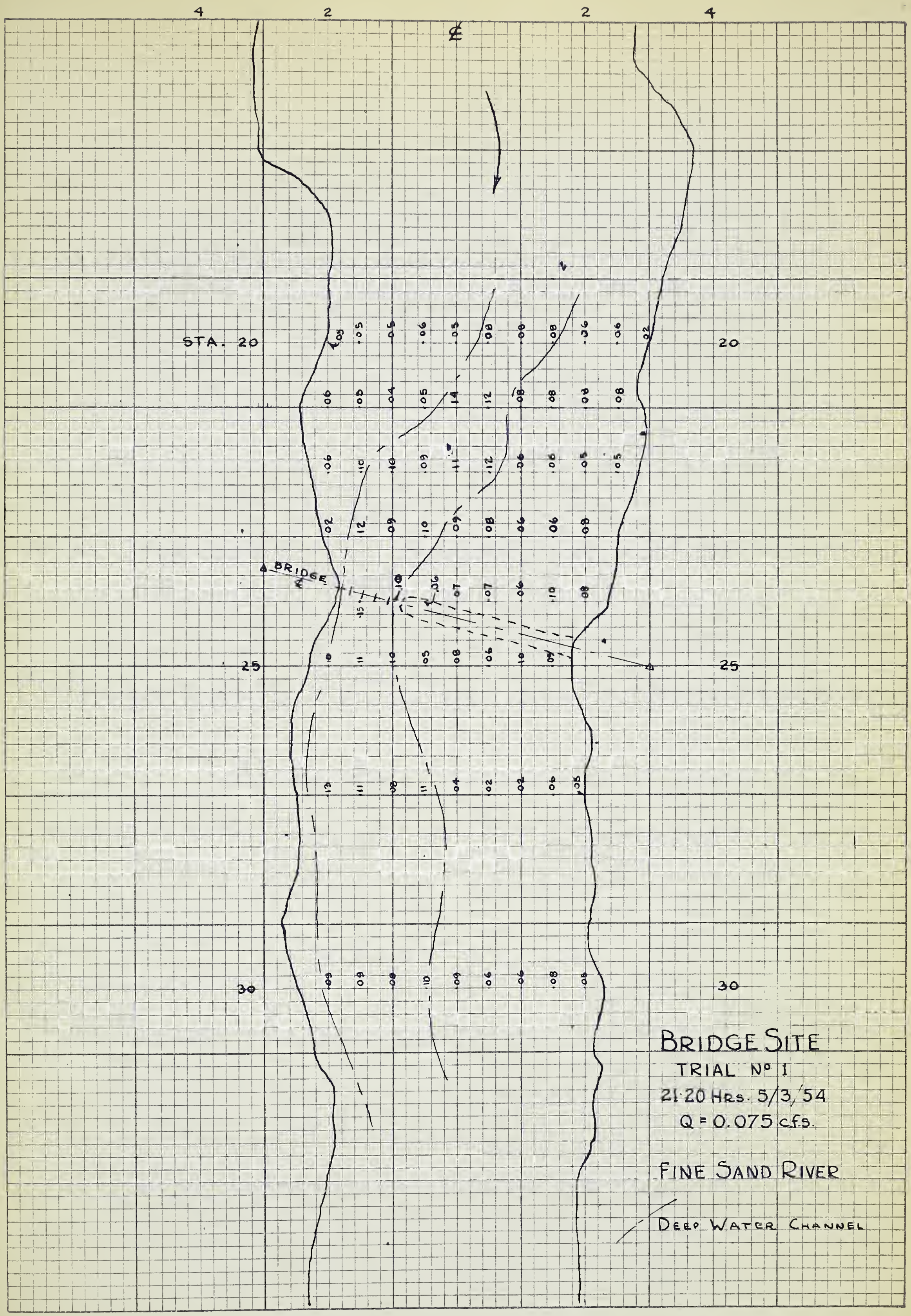
In Trial No. 1 no protection was provided at the abutments and after a period of 40 hrs. both abutments had been washed out, as shown by the full lines in Plate 15.

For Trial No. 2 the abutments were rebuilt, as shown by the dashed lines on Plate 15, and some stone protection added. The stone, as placed, provided little protection for the abutments as it was eventually washed out. Plate 16 shows the area at the end of this trial. In Trial No. 3 a very much larger amount of stone was placed around the abutments, and the size of the abutments increased. At the time of writing the abutments are still intact.

The observed scour around the piers has checked very closely with calculation. Maximum calculated scour was 0.35' and the maximum observed scour was 0.30' just after the abutments were rebuilt as shown in Plate 16.

Plates 14, 15 and 16 also show the effects of the bridge and road on the main channel and the banks up and downstream from the bridge site. Very rapid bank erosion was noted at station 30. To prevent this from continuing a spur was constructed at station 28, Plate 15. Plate 16 shows little increase in the extent of the erosion.

A normal sequence of trials would continue trying various other training works (guide banks, pitched islands) and studying the effects of these on the river up and downstream and at the bridge site. From the results would be chosen the most practical training works for this type of bridge site.



STA. 20
BRIDGE
BRIDGE SITE
TRIAL Nº 1
21·20 HRS. 5/3/54
Q = 0.075 c.f.s.
FINE SAND RIVER
DEEP WATER CHANNEL

PLATE Nº 14

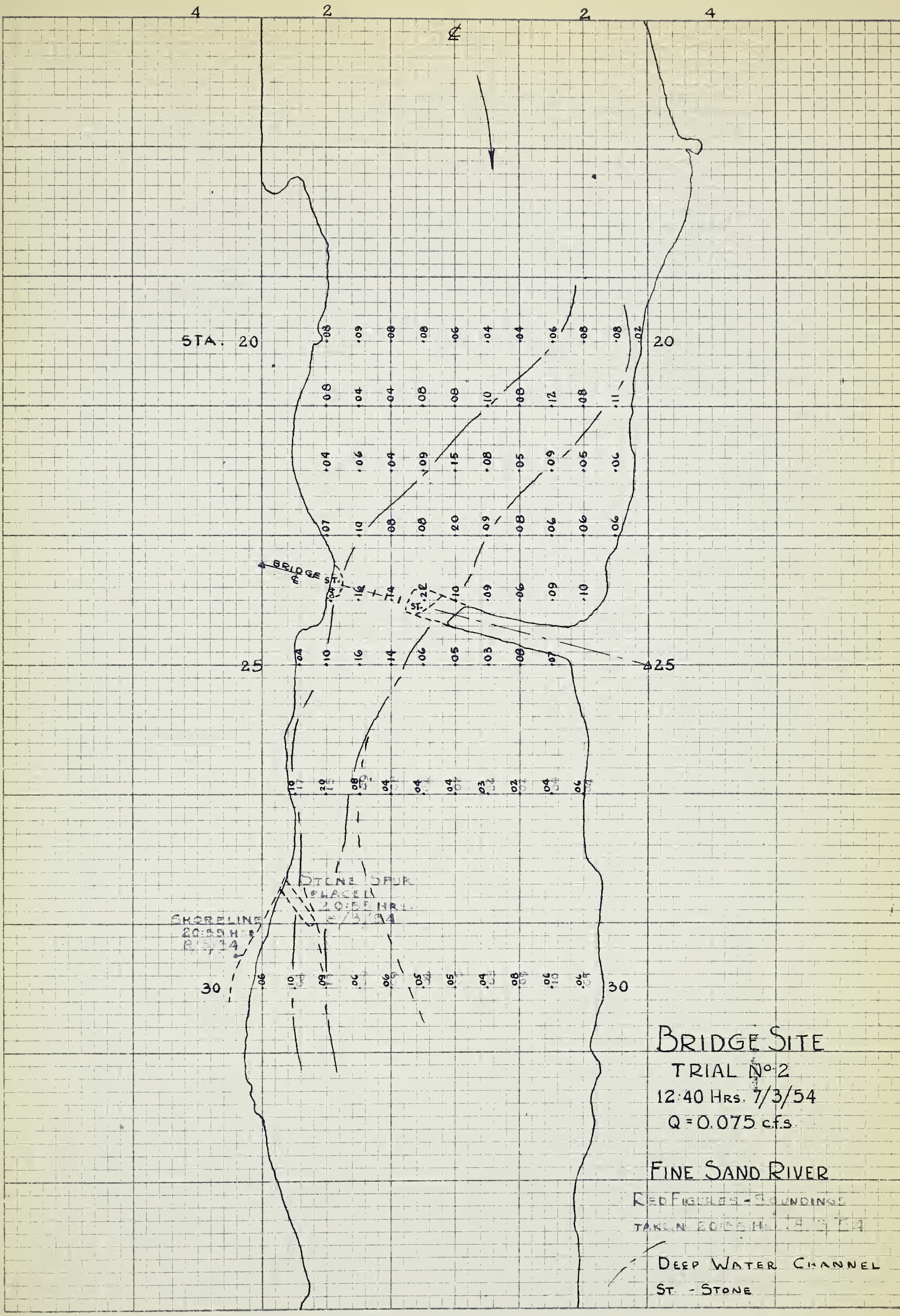
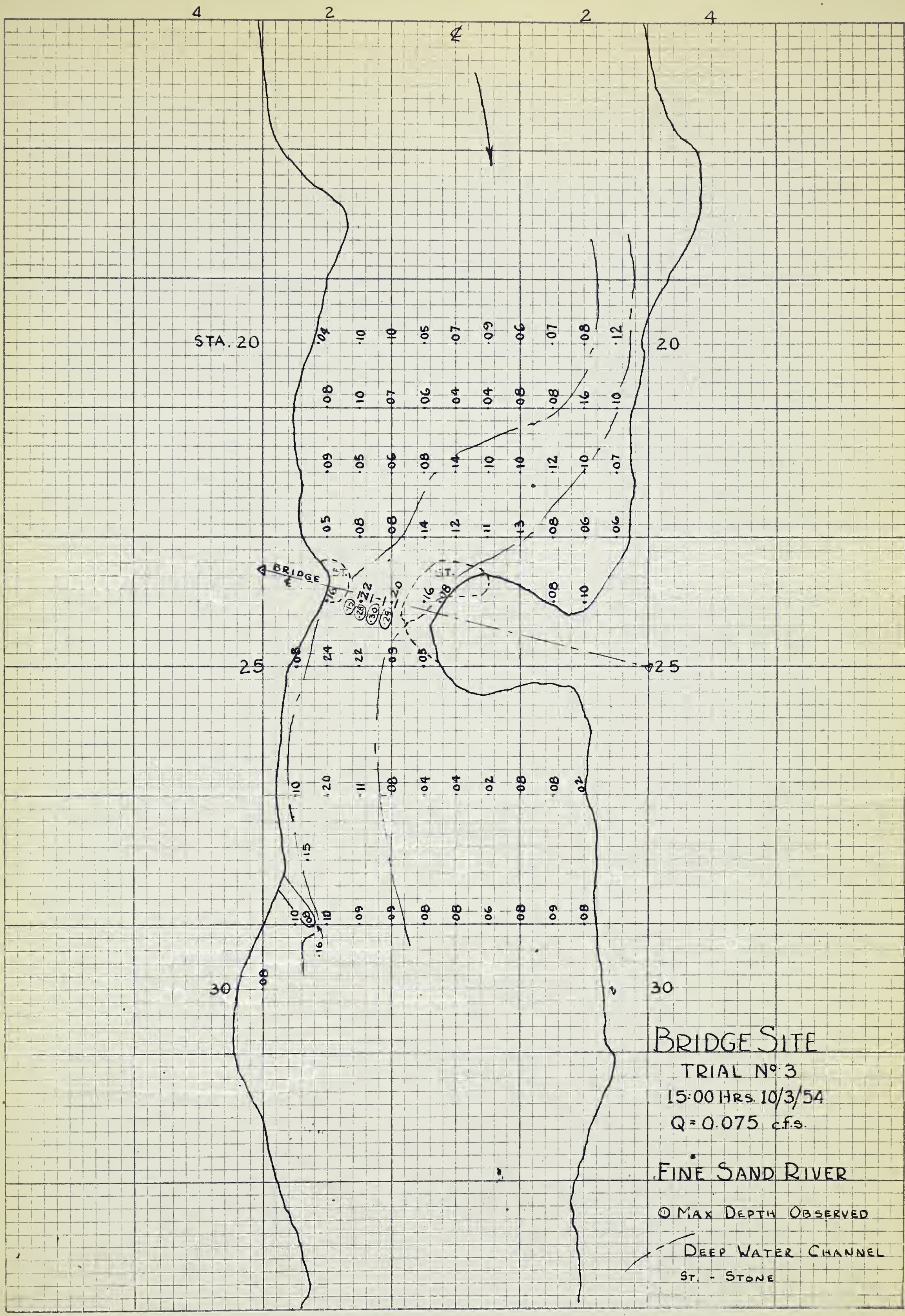

STA. 20
25
30
BRIDGE ST.
ST.
STONE SPUR
SHORELINE
BRIDGE SITE
TRIAL No 2
12:40 Hrs. 7/3/54
Q = 0.075 c.f.s.
FINE SAND RIVER
DEEP WATER CHANNEL
ST. - STONE

PLATE No.15



BRIDGE SITE

TRIAL Nº 3

15:00 HRS. 10/3/54

Q = 0.075 c.f.s.

FINE SAND RIVER

○ MAX DEPTH OBSERVED

DEEP WATER CHANNEL

ST. - STONE

PLATE Nº 16

During the Preliminary Test a trial filming of the tray was made. This was successful and the experience gained was used to advantage in the filming of Test No. 1. From the films it is possible to study rates of development of meandering and obtain a "speeded-up" sequence of the development. Later filming will cover local areas, bridge sites and other river control structures, to obtain a complete sequence of the effect of these structures on the river.

The films are on file with the Department of Civil Engineering.

Outline of Possible Future River Tray Studies

1. Continuation of study of river control at bridges, with constant and varying discharges.
2. Study of the effects of fluid and solid discharge on meander length and width.
3. Study of water surface and bed slopes, local and overall, at various discharges.
4. Study of bed wave length and height at various discharges and the direction of their movement relative to the main channel flow.
5. Qualitative studies of various river training works.

APPENDIX I

Summary of Regime Formula

The following terms are used:

D - Depth of flow from water surface to bed in ft.

W - Mean width in terms of depth D, so that WD = cross-sectional area of flow; in ft.

S - Slope of channel; nondimensional

Q - Discharge in cfs

ν - Kinematic viscosity in sq. ft. per sec.

V - Mean speed of flow in ft. per sec.

Mb - Meander breadth in ft.

Ml - Meander length in ft.

Cb - Coefficient of meander breadth

Cl - Coefficient of meander length

T - Time in seconds

r - Scale ratio

q - Discharge intensity, $\frac{Q}{W}$ in cfs/ft.

The bed factor is defined by

$$b = \frac{V^2}{D}$$

The side factor is defined by

$$s = \frac{V^3}{W}$$

$$W = \sqrt{\frac{bQ}{s}}$$

Appendix I (cont'd.)

$$D = \sqrt[3]{sQ/b^2} = \sqrt[3]{\frac{q^2}{b}}$$

$$\phi = \frac{b^{5/6}\ s^{1/12}}{2080Q^{1/6}\ c}$$

where c is $(10^{-5}/\nu)^{1/4}$

$$(T)_r \doteq \left(\sqrt[3]{\frac{bQ}{s^2}}\right)_r$$

APPENDIX II

Equipment List (Major)

Article	Supplier
Pumps	Canadian Fairbanks Co., Edmonton
Camera and Attachments	Training Aids Inc., Sherman Oaks, California
Vibrating Point Limnigraph	Laboratoire Dauphinois d'Hydraulique, Grenoble, France
Visual Accumulator Analysis Recorder	Specialty Engineering Inc., St. Paul 3, Minnesota

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